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CONF-890422--1

DE89 008725

A PERSPECTIVE ON HUMAN EXPOSURE TO PCDDs AND PCDFs EMITTED FROM MUNICIPAL WASTE COMBUSTORS

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* Research was sponsored by the U.S. Environmental Protection Agency under an Interagency Agreement applicable under Martin Marietta Energy Systems, Inc., Contract No. DE-AC05-84OR21400 with the U.S. Department of Energy.

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A PERSPECTIVE ON HUMAN EXPOSURE TO PCDDs AND PCDFs EMITTED FROM MUNICIPAL WASTE COMBUSTORS

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ABSTRACT

This paper discusses the following key issues concerning human exposure to polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) emitted from modern municipal waste combustors (MWCs): (1) Are MWCs the major source of PCDD/PCDF input into the environment? (2) Are environmental concentrations around MWCs substantially elevated relative to background levels? and (3) Are MWCs the major source of human exposure to PCDDs and PCDFs? Current scientific evidence indicates that: (1) combustion sources in general (including steel mills, copper smelting plants, motor vehicles, hospital incinerators, and MWCs) are major sources of PCDD/PCDF input in the environment; (2) environmental concentrations of PCDDs and PCDFs around operating MWCs are not substantially elevated; and (3) 99% of human exposure to PCDDs and PCDFs is from background environmental contamination, even for individuals living near a modern municipal waste combustor.

INTRODUCTION

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), including the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, commonly referred to as "dioxin"), are the subject of much public concern and debate. Because TCDD is the most potent chemical carcinogen ever evaluated by the Environmental Protection Agency (1), there is s[eculation that exposure to even small amounts of dioxin could lead to serious adverse human health effects. As the controversy surrounding municipal waste combustion intensifies, government agencies, public officials, and the public, question if municipal waste combustion is a feasible waste management alternative. Because it has become a formidable challenge for any one individual to critically evaluate the myriad of information available, the majority of the general public and segments of the scientific community seem

to have a limited knowledge of some key issues which are critical to but often overlooked in this debate.

This paper is not intended to resolve the incineration debate but to examine the following three issues concerning human exposure to facility-emitted dioxins and furans: (a) Are municipal waste combustors (MWCs) the major source of PCDD/PCDF input into the environment? (b) Are environmental concentrations of PCDDs/PCDFs around MWCs substantially elevated? and (c) Are MWCs the major source of human exposure to PCDDs and PCDFs?

We acknowledge that many people are quite concerned about dioxin emitted from MWCs and that the existing data concerning environmental concentrations of dioxin are not sufficient to make any definitive statements. It is not our position that MWCs are safe, nor are we recommending municipal waste combustion as the optimum solution to waste disposal problems. Many other issues (such as health risks associated with ash management and the economic aspects of incineration) are not addressed in this paper and require further investigation. Our analysis, however, indicates that: (a) combustion sources in general (not just MWCs) are the major source of environmental dioxin; (b) background levels of dioxin are alarmingly high; and (c) dioxin levels near MWCs are not substantially elevated relative to background levels. Thus, individuals expressing concern over dioxin emissions from MWCs need to produce data and analyses showing why that concern is warranted.

ISSUE 1 - ARE MWCs THE MAJOR SOURCE OF PCDD/PCDF INPUT INTO THE ENVIRONMENT?

PCDDs and PCDFs are formed during many combustion processes (2). Principal environmental sources of PCDDs and PCDFs are suspected to be: (a) industrial sources, including metal processing and treatment plants, pulp and paper mills, steel mills, and copper smelting plants (3-6); (b) motor vehicle emissions (7-9); (c) chemical manufacturing processes (10); (d) combustors, including chemical, industrial, hospital, and municipal waste combustors (10-12); and (e) forest fires and residential wood burning (12,13).

INDUSTRIAL SOURCES

Marklund *et al.* (3) and Rappe *et al.* (4) reported that PCDD/PCDF emissions from high-temperature industrial processing plants, such as steel mills and copper smelting plants, seem to be of the same magnitude as emissions from MWCs. The Swedish EPA (14) estimated that emissions of PCDDs and PCDFs from these types of plants in Sweden range from 50 to 150 grams of Toxic Equivalents Dioxins and Furans (TEDFs) per year, while normal-sized, modern MWCs (50 to 200,000 tons of waste per year capacity) emit about 1 to 100 grams TEDFs per year (15,16). [The toxicity of different PCDD and PCDF isomers is typically expressed in terms of TEDFs, which relates the toxicity of all PCDD/PCDF compounds to the known toxicity of TCDD using one of several weighing schemes (17)]. Because there are many more industrial sources,

however, their contribution to total PCDD/PCDF input could be much greater than the contribution from MWCs (4). Thus, various researchers argue that industrial sources may contribute equal or even larger amounts of PCDDs and PCDFs into the environment than MWCs.

MOTOR VEHICLES

Studies have shown that motor vehicle emissions may be a larger source of PCDD/PCDF input than MWCs. Ballschmiter *et al.* (7) argued that a more prevalent source of PCDD/PCDF input than municipal waste combustion must exist to account for the widespread background contamination of PCDDs and PCDFs and suggested that the ubiquitous, non-point character of motor vehicle emissions "strongly recommends this source for consideration as a major environmental input."

Marklund *et al.* (8) found that total emissions of PCDDs and PCDFs from cars in Sweden using unleaded gasoline were 10 to 100 grams TEDFs (Eadon method) per year, which is equivalent to the amount of PCDDs and PCDFs emitted from two to 20 MWCs of normal size and technology. Thus, in Sweden, motor vehicles and MWCs emit about the same amount of PCDDs and PCDFs. Jones (18) reached the same conclusion for the United States and contended that since motor vehicle emissions are so widespread, roadside exposures are equal to or greater than exposures to PCDDs and PCDFs emitted from MWCs.

Rappe *et al.* (9) measured PCDD/PCDF levels in ambient air from (a) a traffic tunnel; (b) an industrial area 1500 meters downwind of a MWC; and (c) a suburban area 13 kilometers from Hamburg, West Germany. PCDD/PCDF levels in the traffic tunnel [28 picograms/cubic meter of air (pg/m^3)] were two times higher than levels downwind from the MWC (13 pg/m^3) and nine times higher than the suburban air concentration (3.0 pg/m^3) (9). Rappe et al. (9) concluded that "measurements made in the traffic tunnel clearly indicate that motor vehicles are a source of PCDDs and PCDFs in the ambient air." Hence, several researchers confirm that motor vehicle emissions may also be a significant source of PCDD/PCDF input into the environment. It should be noted, however, that these two studies evaluated emissions from European motor vehicles and apply only to vehicles run on leaded gasoline. The contribution of vehicles run on unleaded gasoline and diesel fuel has yet to be determined.

PULP AND PAPER MILLS

Pulp and paper mills that use chlorine bleaching processes may be another source of PCDD/PCDF input (19). Tests conducted at mills using a chlorine bleaching process showed that: (a) TCDD is formed in trace amounts during the bleaching of hard- and softwood pulps with chlorine and chlorine derivatives, and (b) the relative amounts of TCDD found in mill discharges varied dramatically from mill to mill (20). Swanson *et al.* (6) analyzed the effluents from mills in Sweden that use such processes and found that PCDD/PCDF releases ranged from 2 to 5.8 g TEDFs (Eadon) per year. They estimated that all pulp and paper mills in Sweden as a whole discharge 5 to 15

g TEDFs per year. Their preliminary findings suggest that the amount of PCDDs and PCDFs emitted from pulp and paper mills in Sweden is small relative to other known sources.

OTHER SOURCES

Sheffield (13) estimated that forest fires in Canada release 58,700 grams of dioxins per year, while residential wood burning may input an additional 1,800 g/year and concluded that "forest fires are estimated to be the largest source of PCDD release to the environment." Bumbaco (21) quantified PCDDs and PCDFs emitted from a hospital incinerator in Victoria, British Colombia. Average PCDD/PCDF emissions from this single incinerator was 23 g/yr, which suggests that hospital incinerators may be a dominant source of environmental PCDDs and PCDFs.

SUMMARY

These data indicate that combustion processes in general (not just MWCs) are candidate sources of PCDD and PCDF input into the environment and that it is premature to conclude that MWCs are the major source. The magnitude of PCDDs and PCDFs released from other combustion sources known to emit dioxins and furans (i.e., copper smelting plants, steels mills, motor vehicles, and hospital incinerators) needs to be quantified before definitive statements about the major source(s) of PCDD/PCDF input can be made.

ISSUE 2 - ARE PCDD/PCDF CONCENTRATIONS AROUND MWCs ELEVATED?

To determine if environmental concentrations of PCDDs and PCDFs around operating MWCs are truly elevated, they must be evaluated in the context of background environmental concentrations to which individuals are continuously exposed. Measured concentrations of PCDDs and PCDFs in air, soil, and animal samples obtained from sites near operating MWCs are scarce. The existing data, however, provide little evidence that PCDD/PCDF concentrations around these facilities are substantially elevated relative to existing background levels.

URBAN AIR

Table 1 shows that urban air concentrations are remarkably similar in all industrialized countries where measurements have been made (U.S., West Germany, Sweden, Japan, and New Zealand), ranging from 1.3 to 9.6 pg/m^3, with a geometric mean concentration of 3.4 pg/m^3.

TABLE 1. CONCENTRATION OF PCDDs AND PCDFs IN URBAN AIR

Location	Concentration (pg/m^3)	Reference
West Germany	3.0	9
West Germany	8.7	22
U.S. (Indiana)	2.2	23
U.S. (New York)	2.5	24
U.S. (California)	9.6	25
U.S. (Ohio)	4.5	26
Japan	8.7	27
Sweden	1.3	28
New Zealand	6.7	29
Geometric mean	4.3	

We could locate only one study, however, that reported both background urban air concentrations and the concentration of PCDDs and PCDFs in air near an operating MWC. Rappe *et al.* (9) found that measured concentrations of PCDDs and PCDFs in air near an operating MWC in West Germany (13.0 pg/m^3) were about four times higher than measured background air levels in West Germany (3.0 pg/m^3). That same study, however, found that PCDD and PCDF levels in air 100 meters from a motorway and 600 meters from a copper smelting plant (34.0 pg/m^3) were about 11 times higher than measured background air levels and three times higher than levels measured around the MWC (9). These data support the theory that numerous combustion sources (not just MWCs) are contributing to elevated levels of PCDDs and PCDFs measured in the ambient air of industrialized countries.

URBAN SOIL

PCDD/PCDF levels measured in background urban soil and in soil around operating MWCs are presented in Table 2.

TABLE 2. CONCENTRATION OF PCDDs AND PCDFs IN URBAN SOIL AND IN SOIL FROM SITES NEAR OPERATING MWCs.

Location	Levels in urban soil (ng/g)	Levels near MWCs (ng/g)	Reference
United States	1.32	NA[a]	30
Japan	NA[a]	5.30	31,32
Canada	1.82	0.38	33
Italy	0.01	0.25	34
Denmark	0.29	0.21	35
Geometric mean	0.29	0.57	

[a] Measurement not taken

Yasuhara *et al.* (31) and Morita *et al.* (32) measured PCDD/PCDF levels in soil near four MWCs in Japan. (Incinerator type, age, and distance from the incinerator at which samples were taken were not specified). The geometric mean concentration of those samples (5.3 nanograms (ng)/g) is about 18 times higher than the mean world background concentration (0.29 ng/g) but only about three times greater than the US/Canada mean background urban concentration (1.6 ng/g). Since background concentrations of PCDDs and PCDFs in Japanese soil were not reported, it is impossible to determine if soil concentrations near these incinerators were elevated relative to background levels.

McLaughlin and Pearson (33) measured soil concentrations of PCDDs and PCDFs at 11 sites 0.1 to 2.1 kilometers (km) away from the SWARU MWC which has been operating in Hamilton, Ontario, Canada, since 1973, and at two urban sites 4.5 and 5.6 km away. The geometric mean concentration for the 11 sites near the MWC (0.38 ng/g) was about five times lower than the geometric mean concentration for the two urban sites (1.82 ng/g) but equivalent to the world background concentration (0.29 ng/g).

Berlincioni and di Domenico (34) assayed soil samples collected from five sites within a one km radius of a MWC which has been operating in Florence, Italy, since 1973. Background levels were determined at two sites eight km from the MWC. The geometric mean concentration near the MWC (0.25 ng/g) is 25 times higher than Italian background levels (0.01 ng/g) but

virtually identical to mean world background levels (0.29 ng/g).

Finally, Nielsen and Lokke (35) examined soil samples from three "relatively unpolluted sites" 0.1 to 0.5 km from a small MWC and found that PCDD/PCDF concentrations near the MWC (0.21 ng/g) were not elevated relative to Danish or world background concentrations (0.29 ng/g). Depending on release point and plume characteristics, however, maximum soil concentrations may have occurred further away from the incinerator.

These data are not sufficient to make definitive statements about whether the concentration of PCDDs and PCDFs around operating MWCs are substantially elevated. For example, if the Japanese data are included in the geometric mean, soil levels near MWCs appear to be about two times higher than background concentrations. Conversely, if the Japanese data are not included in the geometric mean, PCDD/PCDF levels near MWCs are not elevated relative to background concentrations.

COW MILK

Although analysis of dioxin in commercial milk is limited, existing measurements indicate global contamination of dairy products. PCDD/PCDF levels in commercial milk samples (whole milk basis) from industrialized countries range from 0.6 to 3.1 pg/g, with a geometric mean concentration of 1.1 pg/g (Table 3). Rappe *et al.* (15) analyzed single milk samples from cows that grazed on farmland located: (a) 16 km from a small MWC and 20 km from a large MWC near Bern, Switzerland; (b) 0.2 to one km from a medium-sized MWC near Hunzenschwil, Switzerland; (c) 0.3 to one km from the same MWC in (b); and (d) one km from a production site for chlorinated products in Rheinfelden, West Germany. PCDD/PCDF concentrations for the three MWC samples ranged from 0.84 to 3.2 ng/kg, with a geometric mean concentration of 2.2 ng/kg, which is two times higher than world background concentrations. Mean PCDD/PCDF levels in milk taken from cows grazing near the production plant for chlorinated products (2.7 pg/g), however, were slightly higher than levels in the MWC samples (15), which demonstrates that other processes (not just MWC) are capable of contributing to elevated levels of PCDDs and PCDFs in cow milk.

TABLE 3. CONCENTRATION OF PCDDs AND PCDFs IN COMMERCIAL MILK SAMPLES[a]

Country	Concentration (pg/g)	Reference
Switzerland	0.56	15
West Germany	0.81	36
Japan	0.99	37
Canada	3.10	38
Geometric mean	1.1	

[a] Whole milk basis

ISSUE 3 - ARE MWCs THE MAJOR SOURCE OF HUMAN EXPOSURE TO PCDDs and PCDFs?

The food chain is the major source of human exposure for a large class of organics, including PCBs, pentachlorophenol, DDT, TCDD, and most pesticides (39-41). Travis and Hattemer-Frey (40) found that the food chain, especially beef and dairy products, accounts for 98% of human exposure to TCDD. Market basket studies conducted in West Germany, Canada, and Japan show that the mean background daily intake of PCDDs and PCDFs (expressed in TEDFs) in industrialized countries is about 98 pg TEDFs/day (Table 4).

Travis and Hattemer-Frey (16) evaluated risk assessments prepared for 11 proposed MWCs and estimated that the geometric mean daily intake of dioxins and furans by the maximally exposed individual living near a typical, modern MWC is 0.6 pg TEDFs/day. These data show that average daily intake of PCDDs and PCDFs by the maximally exposed individual living near a typical, modern MWC is due mostly to exposure to background PCDD/PCDF contamination. In fact, one receives 13 times more dioxin from drinking a liter (L) of milk (background concentration = 1.1 ng/L) than from breathing "dioxin-laden" air around a MWC for one day (background concentration = 4.2 ng/m^3 times 20 m^3 of air inhaled per day).

TABLE 4. AVERAGE DAILY INTAKE OF PCDDs AND PCDFs (EXPRESSED IN TEDFS[a]) BY THE GENERAL POPULATION OF INDUSTRIALIZED COUNTRIES

Country	Daily intake[b] (pg/day)	Reference
West Germany	90	42
Japan	84	43
Canada	125	38
Geometric mean	98	

[a] Toxic Equivalents Dioxins and Furans

[b] Exposure estimates were adjusted to reflect the dietary intake of an individual weighing 70 kg.

These data indicate that human exposure to dioxin emitted from a typical, state-of-the-art MWC is small relative to exposure to background environmental contamination, since exposure to MWC emissions (0.6 pg/day) accounts for less than 1% of the total daily intake of PCDDs and PCDFs (98 pg/day). One might question why, if measured environmental concentrations of PCDDs and PCDFs around operating MWCs are near background levels (see Tables 1 through 3), is the incremental daily intake of PCDDs and PCDFs by the maximally exposed individual living near a typical, modern MWC so small? One reason is that risk assessments prepared for proposed MWCs generally assume that only a small percentage of food is locally produced and consumed. For example, only about 5% of vegetables and produce consumed nationwide is home grown. As a result, ingestion is often not the primary pathway of human exposure. In areas of high agricultural production, however, the 0.6 pg TEDFs daily intake estimate for MWCs could be low.

CONCLUSIONS

It is currently popular among various regulatory agencies and environmental groups to blame MWCs as the major source of PCDD/PCDF input into the environment. Empirical evidence shows that MWCs are one source of PCDD/PCDF input into the environment. The same data, however, indicate that it is premature to blame MWCs as the major source of PCDD/PCDF input. The relatively small contribution of MWCs to total daily intake of PCDDs and PCDFs suggests that some, as of yet unidentified, source(s) (possibly automobiles or industrial sources) are substantially contributing to background levels of dioxins and furans (16). Given the relatively high background levels of PCDDs and PCDFs, it is imperative that environmental sources of dioxins and furans be identified and quantified. Research efforts need to stress:

- Determining environmental levels of PCDDs and PCDFs in air, soil, and vegetation;
- Determining background human exposure to PCDDs and PCDFs through market basket studies;
- Quantifying the magnitude of emissions from and levels of PCDDs and PCDFs in environmental samples near facilities known to emit dioxins and furans (e.g., steel mills, copper smelting plants, MWCs, etc.), so that the major contributors to the high background levels can be distinguished;
- Quantifying PCDD/PCDF emissions from vehicles that use unleaded gasoline and diesel fuel.

Given the intense public concern about dioxin, it is surprising that the EPA has yet to undertake one of the above research objectives.

The work described in this paper was funded by the U.S. Environmental Protection Agency, but this paper has not been reviewed in accordance with the Agency's administrative review policies. Therefore, the contents of this paper do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

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